Available online at www.sciencedirect.com
ScienceDirect
Renewable and Sustainable Energy Reviews
12 (2008) 1476–1484

RENEWABLE
& SUSTAINABLE
ENERGY REVIEWS

www.elsevier.com/locate/rser

Positive externalities of domestic biogas initiatives: Implications for financing

Sunderasan Srinivasan*[,1]

Verdurous Solutions Private Limited, Mysore, India

Received 15 December 2006; accepted 5 January 2007

Abstract

Domestic biogas programs are often justified on the basis of the private benefits and costs accruing to the individual households, in terms of providing a superior cooking fuel, improved indoor air quality and saving of time spent on collecting firewood. This paper contends, however, that the economic surpluses from domestic biogas programs are realized beyond such narrowly defined project boundaries. The paper maintains that economic value addition from the consumptive use of the biogas for cooking and the non-consumptive and indirect value derived from the biogas plant providing feedstock for other processes and other such benefits as greenhouse gas mitigation (positive externalities) need to be accounted for. The process approach adopted by this paper would enable an integrated view of the value chain and consequently, a mechanism to reallocate costs and to distribute such surpluses.

Keywords: Domestic biogas digesters; Microfinance; Function mapping; Positive externalities

Contents

*Tel./fax: +91 821 2510 553.
E-mail address: sunderasan@yahoo.com.
URL: http://www.verdurous.in.
[1]Disclaimer: The views expressed in this article are of the author himself and do not necessarily reflect those of any organization.

1364-0321/$ - see front matter
doi:10.1016/j.rser.2007.01.004

1. Background

Biogas digesters have come to symbolize access to modern energy services in rural areas and are slated to considerably improve health and sanitation, and to yield significant socio-economic and environmental benefits. The gas released from the anaerobic digestion of animal residues, when used as a cooking fuel, provides for superior combustion and displaces dirtier and less efficient cooking fuels, viz., firewood. By reducing indoor smoke and consequent ocular and respiratory infections, biogas digesters contribute to improved health and to proportional reductions in medical expenditure. The surplus gas could be put to use on other applications, viz., water and space heating [1], and could potentially replace conventional alternatives. Batzias et al. [2] have evaluated energy and biogas potential of livestock residues and have presented a GIS-based biomass resource assessment application to explore the possibility of upgrading the biogas and transporting it through a nationwide pipeline network. Plant owners have the option of linking sanitary toilets to the digesters thus improving hygiene, though this proposition often encounters social reluctance.

Promotional measures, interest subsidies and cost buy-downs encourage construction of biogas plants but do not necessarily, ensure continued operation, which is essential for the environmental benefits and consequent cash-flows to accrue. The convenience of cleaner fuel with superior combustion and one providing for improved indoor air quality is, by itself, not adequate motivation to alter lifestyles, especially in the face of handy availability of alternatives such as fuel wood. Further, inadequately informed farmers fail to distinguish between raw animal residues and the digestate, thereby wasting the superior manurial value of the latter. Microfinance schemes for the biogas program in developing countries, thus, have to be designed to *facilitate* the construction of new plants, and more importantly, provide *incentives* for sustained operation. Such facilitation could take the form of working capital facilities for vendors, awareness campaigns and quality assurance operations. Incentives could emanate from creating markets for raw dung, the gas itself, or the digested slurry priced as above. The microfinance institution (MFI) could diversify its exposure and ensure commercially viable returns on its portfolio, by balancing between low interest credit to individual farmers and commercial terms and equity-like instruments for small business ventures. Multilateral and donor agencies could invest their contributions in the facilitation phase and then pave the way for market mechanisms to sustain the momentum.

2. Value addition from biogas

The benefits of biogas digesters and its products are well known. Construction of the biogas plants generates employment opportunities by itself. Further, women save several hours a day on firewood collection, cooking and cleaning soot deposits off cooking pots. Plant owners, thus, accrue additional benefits from diverting the saved time to productive activities. The slurry produced from the digestion process has superior manurial value as compared to the raw animal waste and finds several applications [3]. As an organic manure, it replaces chemical fertilizers, enhances farm yields and when certified as organic produce, commands premium revenues, especially when exported to developed country markets. The biogas plant effluent is also used as an organic fertilizer in fish polyculture, substantially growing fish yields [4,5], and for various other purposes, including, as an absorbent for removal of lead from manufacturing industry waste water [6].

Several *indirect* benefits flow from large volume installation of family sized biogas digesters. The most notable, of course is the mitigation of methane, a powerful greenhouse gas (GHG) released from the open decomposition of animal wastes and the avoided carbon dioxide release from burning firewood. The reduced use of firewood retards deforestation and the use of organic manures improves the physical, chemical and biological properties of soils while also providing for a vital input to the organic farm trade. Soil regeneration is aided by the farmers resorting to stall feeding their cattle that enables them to capture manure conveniently. As a result, public lands are spared from overgrazing, and are more sanitary.

Domestic biogas programs are often justified on the basis of the *private* benefits and costs accruing to the individual households, in terms of providing a superior cooking fuel, improved indoor air quality and saving of time spent on collecting firewood. For instance, Bala and Hossain [7], evaluate the economics of biogas digesters in Bangladesh in terms of firewood and fertilizer values. Tampier [8] recounts examples across applications and from around the world, and concludes that ‘‘distributed energy utilities’’ could achieve greater market penetration with greater awareness and appropriate consumer financing. This paper contends, however, that the economic surpluses from domestic biogas programs are realized beyond such narrowly defined project boundaries. Such positive externalities imply that the total benefits accruing from the installation of biogas plants exceed the benefits to the individual who receives the service. Society is perhaps, likely to benefit more than the individual recipient does [9].

Lending a time dimension, Pehnt (2006) investigates a dynamic approach to life cycle assessment (LCA) of renewable energy technologies and observes that prospective product and process development would progressively improve the environmental characteristics of such applications. This paper evaluates ripple effects and lays out a framework to estimate the economic value addition from the consumptive use of the biogas for cooking, its non-consumptive (existence) value from disposing raw animal dung, and the *indirect* value derived from the biogas plant providing feedstock for other processes and other such benefits as greenhouse gas mitigation.

3. Review of literature

An analysis of energy balances from a life cycle perspective of large-scale biogas plants operating in Swedish conditions, indicates that the net energy output turns negative when

transport distances of feedstock manure are large [10]. The present article deals with domestic biogas plants which are expected to be sited in close proximity to both the cattle sheds and to cattle farmers' residences where the gas is slated to be consumed, and hence to yield a positive net energy output.

Quadir [11] compares technology to an "invisible leg" capable of moving the economy from one state to the other by providing connectivity, wider access to markets and by preventing waste, resulting in GDP growth rates far greater than those achieved by repeated infusions of foreign aid. Van Groenendaal [12] has computed the net present value of future benefits in various manufacturing sub-sectors and has assessed the demand for a new fuel (natural gas) by forecasting growth in gross value added. Using Vietnam as a case illustration, Dang et al. [13] demonstrate the integration of mitigation and adaptation strategies that can provide additional benefits to social welfare in addition to climate change mitigation. Shi and Gill [14] found that the environmental soundness of technology, viz., biogas digesters alone is insufficient to entice farmers. They list the limited availability of information, risk aversion and high transaction costs as major barriers to the adoption of alternative practices. An objective assessment of benefits and costs and an optimal redistribution thereof, as proposed by this paper, should help overcome cost and risk related barriers.

On analyzing the phase out of leaded gasoline, Hilton [15] concludes that while high income does not guarantee pollution abatement, poverty does not prevent it either, and that "poor nations can and should plan to reduce pollution before they become rich." Lichtman [16] highlights the importance of basing technology deployment programs on an in-depth "understanding of rural resource flows and the local political economy." He suggests that the growth of local organizations would ensure that the "people focus" of development assistance is retained. Malhotra et al. [17] discuss the role of women in household energy management and present a participatory process illustrating their involvement in rural energy decisions.

Allen and Loomis [18] derive non-use and non-consumptive use values for wildlife and arrive at willingness-to-pay estimates, potentially leading to policy decisions that are based on an objective understanding of benefits and costs from forest projects. Brennan [19] analyses "green preferences" and proffers that if sufficient numbers of consumers willingly switch to low-emission technologies, tax or permit policies become less necessary or stringent. Ghosh [20] discusses the possible short-run reduction in farm yields on making the switch from chemical fertilizers to organic manure and recommends that the negative effects could be mitigated through appropriately compensation for the farmers and by promoting a dynamic manure market. This paper envisages that "green" preferences would be made voluntarily, if substantiated by economic incentives and a fair redistribution of benefits and costs, such as through creating a dynamic market for biogas digestate and that compensation required to alter lifestyles would take the form of increased total revenues from organic farm produce.

4. Function modeling

The integrated definition method (IDEFØ) is designed "to model decisions, actions and activities of an organization or system"[2] and is especially useful for functional analyses and

[2]http://www.idef.com/IDEF0.html

for definition of the inputs, outputs, resources employed and the constraints the function is subject to. This article uses the process mapping technique to bring out the differences between the pre- and post-biogas scenarios, Figs. 1a and 1b respectively, and to illustrate the link between a 'first world' consumer's quest for clean air and healthy food, and a biogas plant in a developing country. The map in Fig. 2, further summarizes the private, local and global benefits and beneficiaries from the large scale installation of biogas digesters.

4.1. Private benefits and costs from digester installation

The cash flow streams associated with the ownership and operation of the digester are as follows: cash out-flows on plant acquisition and procurement of the raw dung (or foregone revenue from sale of raw dung) and inflows from avoided firewood procurement costs and from the sale of digested slurry to a downstream process. The improved health of residents and avoided medical expenditure enhances plant owner liquidity. The justification for the investment would be "reasonable" payback periods, approximately overlapping with the tenure of the loans on the plant.

4.2. Benefits of improved health

Health has both direct micro and indirect macro effects on a country's economy; direct through the impact of ill health on current productivity, and indirect via the size and quality of the labor force as determined by such factors as mortality, fertility and intellectual capacity. Studies examining the effect of ill-health at a household level tend to underestimate the full economic impact of ill-health and the benefits from improved health as supply of unskilled and semi-skilled labor tends to be rather inelastic owing to financial compulsions. However, society values the individual health benefits from such applications, for, individuals tend to underestimate the costs imposed on the rest of society by communicable diseases. Mills and Shillcutt [21] have estimated the benefit/cost ratios for malaria control. The have computed that providing 60 million additional children with insecticide-treated mosquito nets with an investment of $1.77 billion would yield a benefit of over $18 billion i.e., a factor of 10.

4.3. Spillover effects and value creation

The firewood collection process is now redundant as is the need for washing of blackened cooking pots, thus, freeing up resources for productive use in the order of several person-hours per day per plant installed. Further, improved health liberates time spent nursing the sick. Surplus time now available could be monetized at prevailing wage rates. The deforestation thus avoided, amounting to about two tons of firewood per average biogas-household creates non-consumptive and indirect value from sequestration. The replacement of kerosene lighting with superior illumination provides for longer study hours for children, with expected positive returns in the medium term.

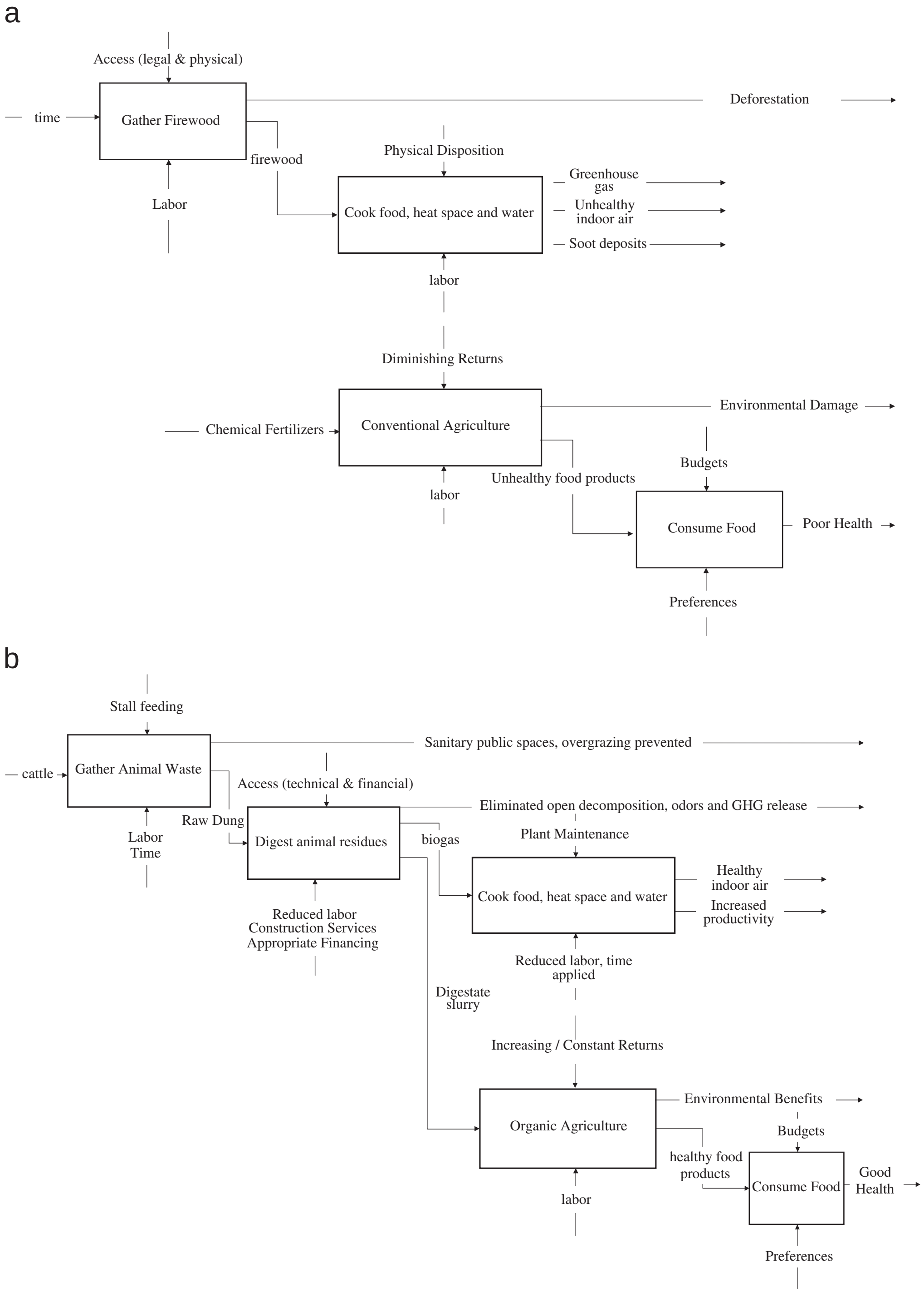

Fig. 1. (a) Pre-biogas plant installation scenario. (b) Post-biogas plant installation scenario.

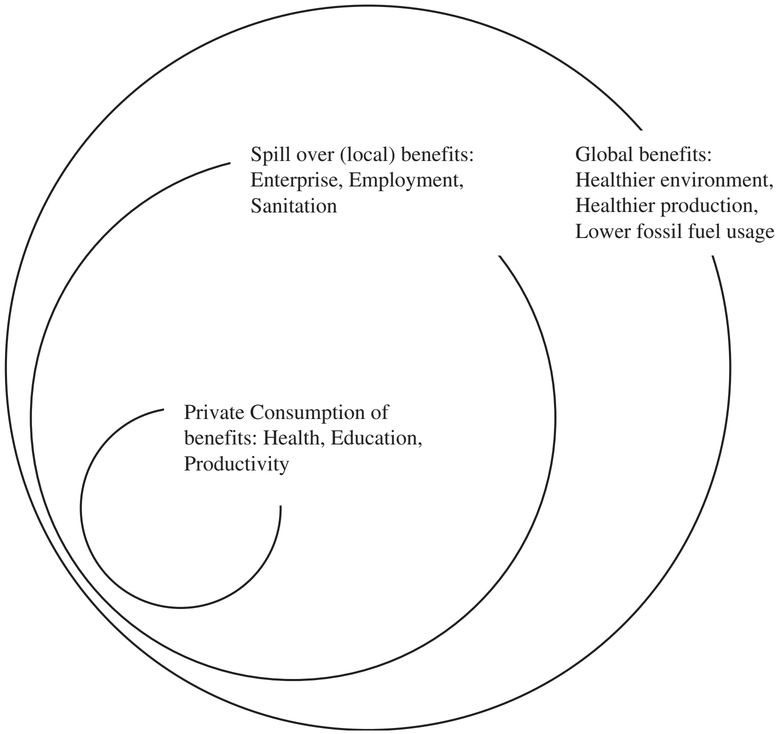

Fig. 2. Private, local and global benefits derived from biogas digesters.

4.4. Social value

The construction and financing of biogas digesters creates employment opportunity by itself, contributing significantly to the rural economy. Stall feeding of cattle to enable convenient collection of dung and linking of sanitary toilets to the digester leads to 'unintended consequences' of avoided overgrazing and more sanitary public spaces.

4.5. Enterprise value creation

The distinguishing aspect of the process approach discussed herein is, portraying the digestate slurry produced from the digestion process as a marketable product, yielding revenue streams to the plant owner household and feeding into a downstream process. The biogas plant is thus rendered a self-liquidating asset, paid for by these subsequent processes.

The market for organic produce is large and growing. Taking note of the rising rates of obesity and compounding problems, viz., diabetes, heart disease, stroke, cancer and birth defects from pesticides, the US Department of Agriculture estimates that healthier diets alone could obviate US $71 billion in annual medical expenses. Concomitant with the increasing awareness that sustainable agriculture works best for both people and nature, the demand for organic products has grown at 20% per annum for the last decade with the US alone consuming about $12.8 billion worth of such food and beverage in 2005 [22].

The Darjeeling Tea R&D Center [23], Government of India, estimates that organically grown teas command a premium of 30–40% over conventionally produced tea and is rendered remunerative despite increased labor intensity and lower productivity in the short run. A portion of this surplus could be invested in securing supplies of superior organic manures emanating from biogas digesters.

The local and regional economy gains from the additional inflows from the sale of organic products and from the cash liberated from medical expenditure. More importantly, the infusion of cash into the local economy gets multiplied by the secondary consumption expenditure it triggers. While the savings provide the MFIs with funds for on-lending, each additional unit of currency entering the local economy from the outside results in more than one unit of additional output and consumption, overall.

4.6. *Global benefits*

The immediately recognized global benefits pertain to the mitigation of green house gas emissions. A secondary impact is the reduction in demand for kerosene and other distillates derived from finitely available fossil fuels. Diminished grazing and retarded deforestation yield sequestration benefits, as well. The plants help secure a steady and increasing supply of labor-intensive organic produce, at which the developing countries clearly enjoy a comparative advantage.

Thus, the case for positive externalities [9] necessitating transfer payments is quite strong, as the total marginal benefit accruing from the biogas plant exceeds the private marginal benefit—possibly leading the individual to undervalue the facility on offer.

5. Conclusion: assignment of benefits and beneficiaries

While the benefits from plant installation and usage flow from the left to the right of the process map, (Fig. 1b), the compensation for the same flows in the opposite direction. The economic agents deriving the health benefits from the consumption of organic produce pay a premium over conventional agricultural produce that compensates the organic farms and ultimately trickles down to the biogas–household in the form of slurry revenues. A second stream, normally in the form of development assistance or of procurement of ‘carbon credits’, offers a relatively less expensive mitigation initiative for a population charged with the responsibility of mitigating carbon emissions (Fig. 2).

Sustainable microfinance programs are required to be consistent with cost recovery and simultaneously to operate on the strength of social collateral and flexibility. Programs enabling the installation of biogas digesters could, thus, de-risk their portfolio by recovering (or securing) a part of their receivables from the organic farmers or cooperatives, who generally tend to be larger and more solvent than small farmers and individual cattle owners. The split in payment responsibility could reflect the (present discounted) value derived from the use of biogas as a cooking fuel and the slurry as an input to the farm. The compensation for global benefits (positive externalities accruing beyond local boundaries) could then be used to foster a conducive environment by building institutions and market practices, viz., awareness creation, quality assurance, etc., benefiting all the agents concerned.

References

[1] Axaopoulos P, Panagakis P. Energy and economic analysis of biogas heated livestock buildings. Biomass Bioenergy 2003;24(3):239–48.

[2] Batzias FA, Sidiras DK, Spyrou EK. Evaluating livestock manures for biogas production: a GIS based method. Renew Energy 2005;30(8):1161–76.

[3] Gurung JB. 1997. Review of literature on effect of slurry use on crop production Biogas Support Program, Nepal, June 1997.

[4] Balasubramanian PR, Kasturi Bai R. Biogas-plant effluent as an organic fertilizer in fish polyculture. Bioresource Technol 1994;50(3):189–92.

[5] Tripathi SD, Karma B. Biogas slurry in fish culture. In: Integrated agriculture–aquaculture: a primer. Fisheries Technical paper no. 407, Food and Agriculture Organization, 2001.

[6] Namasivayam C, Yamuna RT. Waste biogas residual slurry as an adsorbent for the removal of Pb(II) from aqueous solution and radiator manufacturing industry wastewater. Bioresource Technol 1995;52:125–31.

[7] Bala BK, Hossain MM. Economics of biogas digesters in Bangladesh. Energy 1992;17(10):939–44.

[8] Tampier M. Distributed energy utilities—it is all about financing. Renew Energy Access, 22 May 2006 ⟨http://www.renewableenergyaccess.com/rea/news/story?id = 44964⟩.

[9] Clarke GSRG, Wallsten SJ. Universal service: empirical evidence on the provision of infrastructure services to rural and poor urban consumers. In: Brook Penelope J, Irwin Timothy C, editors. Infrastructure for poor people. The World Bank; 2003.

[10] Berglund M, Borjesson P. Assessment of energy performance in the life-cycle of biogas production. Biomass Bioenergy 2006;30(3):254–66.

[11] Economist, 2006. The power to the people, 9 March 2006.

[12] Van Groenendaal WJH. Assessing demand when introducing a new fuel: natural gas on java. Energy Econ 1995;17(2):147–61.

[13] Dang HH, Michaelowa AH, Tuan DD. Synergy of adaptation and mitigation strategies in the context of sustainable development: the case of Vietnam. Climate Policy 2003;3(1):S81–96.

[14] Shi T, Gill R. Developing effective policies for the sustainable development of ecological agriculture in China: the case study of Jinshan county with a systems dynamics model. Ecol Econ 2005;53(2):223–46.

[15] Hilton FG. Poverty and pollution abatement: evidence from lead phase-out. Ecol Econ 2006;56:125–31.

[16] Lichtman R. Toward the diffusion of rural energy technologies: some lessons from the Indian biogas program. World Develop 1987;15(3):347–74.

[17] Malhotra P, Neudoerffer Cynthia R, Dutta Soma. A participatory process for designing cooking energy programmes with women. Biomass Bioenergy 2004;26(2):147–69.

[18] Allen BP, Loomis JB. Deriving values for the ecological support function of wildlife: an indirect valuation approach. Ecol Econ 2006;56(3):49–57.

[19] Brennan TJ. "Green" preferences as regulatory policy instrument. Ecol Econ 2006;56:144–54.

[20] Ghosh N. Reducing dependence on chemical fertilizers and its financial implications for farmers in India. Ecol Econom 2004;49(2):149–62.

[21] Mills A, Shillcutt S. Communicable diseases: summary of Copenhagen consensus challenge paper, 2004 ⟨www.copenhagenconsensus.com⟩.

[22] Cummings CH. Ripe for change: agriculture's tipping point, World Watch Magazine, July/August 2006 World Watch Institute, ⟨www.worldwatch.org⟩.

[23] DTRDC. Organic tea cultivation, The Darjeeling Tea Research and Development Center, Government of India, 2003 ⟨http://www.dtrdc.org/organic.htm⟩.